HR-183 Fatigue Behavior of High Air Content Concrete

Key Words: Fatigue behavior, Air content, Portland cement

ABSTRACT

The need for fatigue strength data in the design of concrete highway and airfield pavements has been known for years. Practically all rigid pavement design procedures used today make use of the fatigue life of concrete. The fatigue curves presently used were last revised in 1966 and do not take into account the effects of entrained air. Thus, this study investigated the effects of air on fatigue strength of plain concrete. All other variables (water-cement ratio, aggregate type, cement type, etc.) were held constant.

Tests were conducted on five batches of concrete with air contents of 2.8, 3.5, 6.4, 10.2, and 11.3%. Fatigue specimens consisted of 6 in. x 6 in. beams subjected to flexural loading under a zero to maximum load cycle. Under such conditions the bottom fiber of the beam was subjected to zero to tension stress cycles. The maximum bottom fiber stress for a specific test in most cases was 60, 70, 80, or 90% of the static modulus of rupture. Concrete for all batches was mixed and poured in the laboratory. Test specimens were stored submerged in water until testing which took place at a specimen age of 28 to 56 days.

Tests were conducted using an Instron Corporation model 1211 dynamic cycler fitted with a one-third point loading frame identical to the one used in the modulus of rupture test. One hundred and twelve fatigue tests were conducted. Results of these tests are presented in both tabular and graphic form. S/N diagrams show a significant reduction in fatigue life as the air content of concrete increases. This reduction is further illustrated when S/N curves with 95% confidence limits for a point are used for pavement design. Using the ISU fatigue curves, a pavement containing 2.8% air would require a design thickness of 7.5 in., while a pavement containing 6.4% air would require a design thickness of 9.0 in.

The main fatigue test program was supplemented by additional investigations. The compressive strength, modulus of rupture, modulus of elasticity, and unit weight were determined for each batch. Plastic air content determinations were compared with hardened air contents determined by the linear traverse and high pressure air meter methods. Scanning electron microscope photographs were taken at various magnifi-cations and various air contents to determine characteristics of the air void system. A mercury penetration porosimeter was used to character-ize the void properties of the concrete at the various air contents.

1. As a result of the various tests performed in this study the following conclusions were reached:The

fatigue behavior of plain concrete in flexure is affected by the air content of the concrete. Fatigue strength decreases as air content increases. Fatigue curves obtained from this study provide a basis for an improved rigid pavement design for pavements in which air-entrained concrete is used. Pavements designed using the high air and low air fatigue curves developed in this study resulted in a difference in thickness of several inches.

2. The linear traverse and high pressure air determination methods are reliable means of ascertaining the air content of hardened concrete and can be used to determine the original plastic concrete air content by mathematical means.

3. The modulus of rupture, compressive strength, modulus of elasticity, and unit weight of concrete all decrease as the air content of the concrete increases.

4. As the air content rises the failure of concrete subjected to fatigue occurs increasingly at the aggregate-cement paste interface. The fatigue failure surface is, however, identical, on a macroscopic level, to the modulus of rupture (static) failure surface.

5. Although it has been generally suggested that entrained air voids are between 1 and 0.005 mm in diameter and spherical in shape, and that entrapped air bubbles are greater than 1 mm in diameter and irregular in shape, the SEM micrographs made in this study showed that the two kinds of voids cannot be distinguished by either size or shape.

6. Air entrainment had essentially no effect on pores of capillary gel size (less than 1 pm). However, mercury porosimetry data showed that at higher air entrainment, increased air resulted in more pores in size of I to 10 pm range, between that of conventional concept of entrained air and capillary pores. Also, increasing air content increased the median pore diameter of the micropores as well as the non-uniformity of pore system.